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PATENT

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TO ALL WHOM IT MAY CONCERN:

Be it known that I, CHRISTOPHER F. O'HARE, a citizen of United States of America, residing in Ocean Ridge, County of Palm Beach, State of Florida, have invented an improvement in

METHOD FOR ASSEMBLING ARTIFICIAL REEF MODULAR UNITS

of which the following is a

SPECIFICATION

BACKGROUND OF THE INVENTION

[0001] This invention relates to artificial reefs assembled from modular units.

[0002] The effectiveness of new artificial reefs and the repair of existing reefs with man-made material have always been influenced by the ability of that material to withstand the adverse effects of tidal, current and wave energy. The buoyancy of the material, i.e., its ratio of weight to water displacement, determines its ability to rest on the bottom of a marine environment. More important is the material's ability to resist movement once placed. While many unstable artificial reefs are created using submerged ships and the like, their intended purpose is to attract divers. Their lack of stability is offset by their ready availability, ease of deployment and entertainment value.

[0003] Stability analyses of various materials in a wave environment indicated that a reef structure's ability to resist the movement forces of a typical storm surge are influenced by the structure's orientation to any oncoming forces, the structure's depth

below the surface of the wave pulse and the weight of each specific reef unit. A reef composed of multiple units will expose each unit independently to the wave forces. A typical artificial reef composed of rubble stone will experience movement of the individual units due to wave force. A similar artificial reef composed of rubble stone with the adherence of interstitial concrete will have a greater resistance to the same wave forces. This is due to the multiple stone units being transformed into a single unit by the addition of the binding concrete.

[0004] The Inman Patent No. 4,397,578 discloses an undersea platform construction system in which concrete modules have mating projections and recesses and each module has a hole which is aligned with a corresponding hole in an adjacent module. Each hole is formed with lateral slots and with a circular recess near the lower end, permitting a T-shaped lifting device to be inserted into the hole with arms passing through the slots and then rotated at the bottom of the hole to place the arms beneath a lifting ledge so as to permit each module to be lifted by the T-shaped lifting device. The construction system can be used for many undersea applications including artificial reefs.

[0005] Patent No. 4,341,489 to Karnas discloses an offshore reef assembled from rows of reef members made of concrete having inclined sides and aligned vertical holes in the central region. In one embodiment tie rods extend through the aligned vertical holes and are threaded to receive nuts retaining a cap in position at the top of the assembly. In another embodiment central tubes are provided in the reef members which are then stacked on a post driven into the floor of the lake or ocean in which the reef is being

assembled. In another embodiment a steel pile extends through the aligned openings and is driven into the floor of the lake or ocean.

[0006] In the McCreary Patent No. 5,087,150 pairs of integral star-shaped blocks are laid over a bottom covering fabric and stacked with central vertical apertures aligned and concrete piling is drilled or poured in place through the apertures to the bottom sediment to hold the structure in place.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a method for joining artificial reef modular units which overcomes disadvantages of the prior art.

[0008] Another object of the present invention is to provide artificial reef modular units which can be assembled to provide an artificial reef which resists the effects of wave action and storm surges effectively.

[0009] These and other objects of the invention are attained by providing an artificial reef assembled from modular units which have through holes and also have mating projections and recesses which assure alignment of the through holes when the modular unit are assembled. In order to join the modular units together securely after they have assembled the aligned through holes are filled with a reinforced concrete mix which when cured bonds to the exposed sides of the through holes, permanently joining the modular units into a unified assembly. In one embodiment a framework of non-corrosive fiberglass rods is inserted through the aligned holes in the modular units and the holes are then filled with a mix of self-compacting concrete specifically formulated for underwater placement.

[0010] In one form of module the through holes extend vertically through the mating projections and recesses of the assembled modules. In another embodiment the through holes are horizontally offset from the mating projections and recesses and, in some cases, are formed by opposed through hole segments in adjacent side surfaces of modular units.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Further objects and advantages of the invention will be apparent from a reading of the following description in conjunction with the accompanying drawings in which:

[0012] Fig. 1 is a cross-sectional view illustrating a representative embodiment of a modular unit for use in assembling an artificial reef in accordance with the invention;

[0013] Fig. 2 is a cross-sectional view illustrating an artificial reef assembled from modular units of the type shown in Fig. 1.;

[0014] Fig. 3 is a schematic perspective view illustrating another form of modular unit for use in assembling an artificial reef in accordance with the invention; and

[0015] Fig. 4 is a schematic cross-sectional view illustrating a portion of an artificial reef assembled from modular units of the type shown if Fig. 3.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] In the typical embodiment of the invention illustrated in Figs. 1 and 2 a module 10 is generally of the type disclosed in Patent No. 6,189,188, the disclosure of which is incorporated by reference herein, and may consist of a cementitious mixture of portland cement, graded limestone aggregates, silica fume, water and commercially available admixtures to enhance resistance to deteriorate in marine environment. The module 10 has top and bottom sides 12 and 14, respectively, and has four sides 16

arranged in a generally rectangular outline as viewed from the top. In the illustrated embodiment each module has two frusto-conical vertical projections 18 from the top surface 12 and two inwardly tapering frusto-conical recesses 20 in the bottom surface 14 which are vertically aligned with the projections 18 and have a shape corresponding to the shape of the projections 18. Each pair of corresponding projections 18 and recesses 20 has a vertical through hole 22 extending from the top of the projection 18 to the bottom of the recess 20 and located in a specific predetermined relation to the projections 18 and recesses 20, preferably being centered therein.

[0017] In order to assemble an artificial reef 44 from a number of the modules 10, the modules are assembled in the manner illustrated in Fig. 2 with the projections 18 of an array of adjacent modules 30a, 30b, 30c... in a layer 30 being received in recesses 20 in modules 32a, 32b, 32c... of a superimposed layer 32 of modules and projections 18 of the modules 32a, 32b, 32c... in the second layer being received in recesses 20 of a third layer 34 of modules 34a, 34b...

[0018] Because all of the through holes 22 in the modules 10 are located in a specific predetermined relation to the projections 18 and recesses 20 they will be in vertical alignment when the modules are assembled in the manner shown in Fig. 2 to provide continuous through holes 22a, 22b, 22c... extending vertically through all of the layers of modules.

[0019] Preferably, as shown in Fig. 2, the shape of the projections 18 and the recesses 20 is selected to provide lateral ring-shaped openings 40 between the bottom surface of

each recess 20 and the top surface of each projection 18 when the modules are assembled into the form of an artificial reef 44.

[0020] After the artificial reef 44 has been assembled, a reinforcing framework of non-corrosive fiberglass rods 46 is inserted into the continuous through holes 22a, 22b, 22c... and each continuous through hole is filled with a tremie mix of self-compacting concrete specifically formulated for underwater placement. The resulting reinforced concrete columns 50 contain embedded fiberglass rods 46 and include lateral projections 52 extending into the openings 40 and a frustoconical enlargement 54 in the lower-most recess 20.

[0021] Thus, the resulting reinforced concrete columns 50 unite the successive layers of modules 30, 32 and 34 not only by reason of their bonding to the inner surfaces of the through holes 22a, 22b, 22c..., but also because of the interengagement of the projections 52 and 54 with the openings 40 and recesses 20 in the module. Moreover, because the through holes 22 in each of the modules are centered in the corresponding projections and recesses 20, the continuous through holes 22a, 22b, 22c... in the assembled modules extend through all of the layers of modules without any deviation, thereby assuring that the columns 50 provide maximum strength in retaining the modules together.

[0022] In the further embodiment shown in Figs. 3 and 4, a module 60 made of concrete in the same manner described above with respect to the modules 10 has a rectangular outline as seen in the vertical direction with opposite long sides 62 and 64 and shorter sides 66 and 68. The module has a central through hole 70 and half through holes 72 and 74 centered in its opposite ends 66 and 68. Intermediate between the central through hole

70 and the half through holes 72 and 74, the top surface 76 of the module has two hemispherical projections 78 at the bottom surface 80 has corresponding hemispherical recesses 82, each of the projections 78 and the recesses 82 being located in specific predetermined relation to the through holes 70 and half through holes 72, preferably halfway between the central through hole 70 and the end half through holes 72.

[0023] In the assembled artificial reef 84 shown in Fig. 4, four layers 86, 88, 90 and 92 containing modules 60 of the type shown in Fig. 3 are assembled with the modules of adjacent layers in horizontally offset relation and each projection 78 being received in a recess 82 of a module in the next higher layer. Because the modules are assembled in offset relation in successive layers and the projections and recesses are located in a predetermined relation to the holes and half through holes, the half through holes 74 at facing ends of adjacent modules are aligned with the through holes 70 in modules in the layers above and below that layer, thereby forming continuous through holes 94 from the top to the bottom of the assembled reef 84. These continuous through holes are then filled with self-compacting concrete of the type described above with respect to Fig. 2, providing reinforced concrete columns 96 which bond to the exposed sides of the continuous through holes 94, permanently joining the modular units into a single assembled reef. If desired, a framework of non-corrosive fiberglass rods can be inserted into the continuous through holes 94 before they are filled with concrete in the manner described above with respect to Fig. 2.

[0024] Because each of the modules in each of the embodiments is provided with projections in its top surfaces and recesses in its bottom surface having a specific

predetermined relation to the through holes, assembly of the modules with the projections and recesses in mating relation assures that the through holes are properly aligned to form a continuous aligned through hole into which a column of concrete can be poured. If desired, the modules 60 can be shaped to provide openings surrounding the bottom or top of each through hole so that the concrete column filling the continuous through hole has lateral projections 50 between the modules of the type described above with respect to Fig. 2.

[0025] It will be understood from the foregoing that it is not necessary for the through holes in each of the modules to be centered either in the projections and recesses or in the top and bottom surfaces of the modules. Instead, the through holes can be located in any portion of the modules as long as all of the modules have through holes or portions of through holes in a specific predetermined corresponding relation to the projections and recesses.

[0026] Moreover, although the artificial reefs shown in Figs. 2 and 4 have adjacent modules all aligned in the same direction, it will be understood that the modules may also be aligned in alternating horizontal directions as shown, for example, in Fig. 3 of Patent No. 6,189,188. Furthermore, a projection and a recess may be on the same side of the modules rather than being on the opposite sides if the location of the projections and the recesses have a specific predetermined relation to each other and to the through holes.

[0027] With the provision of aligned through holes in modules which having mating projections and recesses and concrete columns extending through the through holes in the manner described above, an assembled reef is more resistant to tidal, current and wave

energy, thereby permitting increased placement opportunities for the artificial reef structure and increased duration of the integrity of the structure over long periods of time.

[0028] Although the invention has been described herein with reference to specific embodiments, many modifications and variations therein will widely occur to those skilled in the art. Accordingly, all such variations and modifications are included within the intended scope of the invention.